Preparing for the next decade @ GANIL
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Grand Accélérateur National d'Ions Lourds

A brief overview of the facility
Hot and new (2019) results from the unique tools at the cyclotrons
BREAKING NEWS from the LINAC of SPIRAL2
Next steps
Progress and new opportunities at the Femtoscale@GANIL

Exploring physics of the infinitely small systems under controlled conditions
Impact understanding physics of the infinitely large systems

Cyclotrons+LINAC
Charged particle beams
FAST NEUTRONS
and the state of art instrumentation

Fusion
Evaporation
Multifragmentation
Fission

\[ T \sim 10^{-18} - 10^{-21} \text{s} \]

Key questions: Extremes understanding of how regular and simple patterns emerge in the intrinsic structure of complex many body nuclei

Identifying the degrees of freedom, which govern the dynamics of their collisions.
GANIL and its major upgrade SPIRAL2 -a bird’s X-ray view

**Nuclear Physics /Material science / Atomic physics/ Applications**

**SPIRAL1 (Cyclotrons + CIME):**
- Stable + Short lived beams
  (Fragmentation > 10 µs)

**SPIRAL2 LINAC**
- 33 MeV p, 40 MeV d (5mA)
- 14.5 A MeV HI (1mA)

**Système de Production d'Ions Radioactifs Accélérés en Ligne**

**Breaking News**

**SPIRAL2 PHASE 2 STAND BY**

**SPIRAL2 L1NAC**
- Most intense RIB of fission fragments
- Restart Thinking

**PROJECT X**
- Studies towards Carbon therapy
- Cross sections for $^{211}$Ac...

**Des Ions**

**DRIVER PHASE 2**

**INB113**

**Upgrade SPIRAL1**

**Should be hiring**
Different Tools to address different important questions in an optimum manner at the cyclotrons

Continuous Upgrades
- MUGAST new
- ACTAR new
- FAZAI-INDRA new
- EXOGAM+new electronics+NW+NEDA
- SPIRAL1

VAMOS Improved electronics
AGATA 41 crystals
Excitations of the magic $N=50$ neutron-core revealed in $^{81}$Ga by J. Dudouet et al. Rapid Comm PRC 100 011301 (2019)

Lifetime measurements second $2^{+2}$ state in neutron-rich $^{16}$C and $^{20}$O

Test of ab initio nuclear structure (submitted to PRL)
M. Ciemala et al. Tomorrow 1455 Nuclear structure C

Evidence of octupole-phonons at high spin in $^{207}$Pb
D. Ralet et al. PLB (in press)

Pairing-quadrupole interplay in the neutron-deficient Sn nuclei: first lifetime measurements of low-lying states in $^{106,108}$Sn
M. Siciliano et al (submitted to PRL)
(https://arxiv.org/abs/1905.10313v2)
**First direct measurement of isotopic fission-fragment yields of \(^{239}\text{U}\)**

\[
\text{Be}^{(238\text{U},239\text{U})8\text{Be}}
\]

Transfer induced fission inverse kinematics @ 6 Mev/u

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The increase of the production yield of Sn as a function of fissioning mass in \(^{238}\text{U}\) and \(^{239}\text{U}\) in agreement with Predictions of the Brownian shape-motion model and General Description of Fission Observables (GEF)

The present results disprove the fission yield anomaly for Mo and Sn isotopes reported from recent indirect spectroscopy measurements.

MUGAST+VAMOS campaign 2019 SPIRAL1

Nucleons transfer spectroscopy using the SPIRAL1 ISOL beams VAMOS, MUGAST (MUST2+AGATA)

Gamma rays, protons, deuterons recoils

15O(α,γ)19Ne is at the onset of the rp-process, producing the X-ray bursts. UK+

Protons in the sd shells along the N=28 chain: only spectators

15F unbound states France
gamma transitions in unbound states
2p radioactivity

New Beam development

- 38mK, 28Mg, 15O 45K
- Al and P yields suffering from lower release efficiencies
- More in beam and off beam tests for lots of new beams
- 56Ni next year
2019 ACTAR –ACTIVE TARGET

Commissioning: \(^{18}\text{O}(p,p)\) and \(^{18}\text{O}(p,\alpha)\) excitation functions

\(^{56}\text{Ni} 10^+\) isomer. Germany CENBG 2019

\(^{12}\text{Be}\) structure: search for narrow resonances

\(2p\) radioactivity CENBG
$^{8}\text{He}+^{19}\text{F}$ Charge projection

Beam in-->
(Beam not seen)
Ne recoils
Search for giant monopole resonance in $^{68}$Ni + isopein dependence

ACTAR @LISE e680 Raabe et al June 2019

$^{68}$Ni beam at 49A MeV

$E^*(^{68}\text{Ni}) = 0$ MeV

$E^*(^{68}\text{Ni}) = 10$ MeV

$E^*(^{68}\text{Ni}) = 20$ MeV

Less events in the region of the minimum of the monopole angular distribution (3-4 deg CM) (geometric reconstruction efficiency correction required)

Elastic peak

Online analysis

$^{58}$Ni beam at 49A MeV

M. Vandebrouck

online analysis
Study of superheavy hydrogen $^7$H with one-proton transfer reactions

M. Caamaño (USC), T. Roger (GANIL) et al.

Setup:

$^8$He at 15.4 AMeV on He+CF$_4$ at GANIL

Relevant reactions:
- $^8$He ($^{12}$C, $^{13}$N) $^7$H -> $^3$H+4n
- $^8$He ($^{19}$F, $^{20}$Ne) $^7$H -> $^3$H+4n

The $^7$H reactions are tagged and reconstructed by measuring the recoil angle and range and identifying the scattered product as $^3$H. The kinematics of the proton-transfer reaction can be identified through the range-angle correlation.

Angular distribution:

The statistics allow us to measure the differential cross section, accessing structure information. The data is reproduced with a dineutron dilute condensate skin around a $^3$H core in a $1/2^+$ ground state.

These results show the role of neutron pairing in a closed shell as a source of stability even within the continuum, and confirm the $^7$H as the most stable of the resonance chain despite having the most extreme N/Z ratio of the nuclear chart.
1st experiment of campaign using coupled INDRA & FAZIA charged particle arrays

**Aim**: better constrain isovector component of Nuclear Equation of State (NeoS), density dependence of Nuclear symmetry energy

**Method**: measure energy & impact-parameter dependence of isospin (N/Z) transport around Fermi energies

**Experiment goals**: measure N/Z of projectile-like fragments (FAZIA), mid-velocity fragments (FAZIA/INDRA); sorting by collision violence (INDRA)

**Total beam-time on target**: 38 UT

4 different stable HI beams
At least ~30M events recorded for each projectile/target system

Data reduction in progress

Correlation between charge of fragments detected in FAZIA & violence of collisions (multiplicity) measured by INDRA
Room temperature Cyclotrons to Supercconducting LINAC
Uniqueness to Uniqueness
A Quest for High Intensity

High Intensity

High Statistics

- More Precision
- More Rare Searches
- More Materials

Discovery!

Jie Wei / Y. Yamazaki
That’s one small step for man, one giant leap for mankind.

FINAL COMPLETE permission from the ASN for the running of the FULL facility as per the design specifications on the 8th of July 2019 after almost 6 years since submitting the initial file to the Nuclear Safety authority.
16 days after authorization the first cavity tested has reached the electric field of 8 MV/m beyond the nominal field of 6.5 MV/m

Cavity had been stored for 7 years

- 2MV/m in 2 hours on July 25
- 8MV/m reached in 20 min on July 26!
Towards the first beam through the LINAC

Ion source RFQ He cooling
RF systems, SAFETY SYSTEMS

Characterize, slow ramp of intensity \( p, \alpha \)
Low intensity physics commissioning NFS
Ramp of intensity, \( d \) beam
Full go NFS Autumn 2021
Continuous and quasi-mono-energetic beam
Flight path from 5 to 30 m
High flux of fast neutrons

Should be hiring permanent position and or chair of excellence
Spectrometer

Exotic nuclei ground state properties

High precision techniques

Sensitivity and selectivity
\(N=Z\), Spectroscopy VHE, Laser spectroscopy …

Tomorrow New Facilities and Inst 1410 S. Franchoo et al

MR TOF PIIGRIM New Fac Thursday 1620

\[ \frac{\delta m}{m} \approx 1 \cdot 10^{-9} \]

Start of FULL commissioning End of 2022

Courtesy Klaus Blaum
Summary


The first human-made object to enter interstellar space, traveling "further than anyone, or anything, in history"

Goal at GANIL
Evolution to revolution